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ALASKAN AIR NAVIGATION REQUIREMENTS

Volume III -- FAA Alaskan VHF Omnidirectional Range (VOR) Site Coverage

Robert L. Harlem Henry Bernstein

January 1977

Final Report

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Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
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16. Abstract

Map overlays were developed for 30 existing and 28 proposed VOR sites in Alaska for the Federal Aviation Administration. The overlays were to be utilized to determine the VOR coverage provided by these sites in Alaska. A new terrain-data extraction technique, called the Chromatic Extraction Technique, was developed for this task and is described.

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METRIC CONVERSION FACTORS

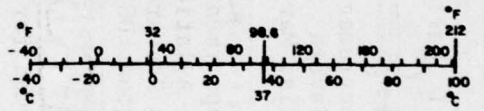
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 238, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
SPECTRUM MANAGEMENT STAFF

STATEMENT OF MISSION

The mission of the Spectrum Management Staff is to assist the Department of State, Office of Telecommunications Policy, and the Federal Communications Commission in assuring the FAA's and the nation's aviation interests with sufficient protected electromagnetic telecommunications resources throughout the world to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource--the electromagnetic radio-frequency spectrum.

This objective is achieved through the following services:

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- Providing research, analysis, engineering, and evaluation in the development of spectrum related policy, planning, standards, criteria, measurement equipment, and measurement techniques.

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- Developing automated frequency-selection computer programs/routines to provide frequency planning, frequency assignment, and spectrum analysis capabilities in the spectrum supporting the National Airspace System.

- Providing spectrum management consultation, assistance, and guidance to all aviation interests, users, and providers of equipment and services, both national and international.

PREFACE

The Electromagnetic Compatibility Analysis Center (ECAC) is a Department of Defense facility, established to provide advice and assistance on electromagnetic compatibility matters to the Secretary of Defense, the Joint Chiefs of Staff, the military department and other DoD components. The Center, located at North Severn, Annapolis, Maryland 21402, is under executive control of the Office of the Secretary of Defense, Director of Telecommunications and Command and Control Systems and the Chairman, Joints Chiefs of Staff, or their designees, who jointly provide policy guidance, assign projects, and establish priorities. ECAC functions under the direction of the Secretary of the Air Force and the management and technical direction of the Center are provided by military and civil service personnel. The technical operations function is provided through an Air Force sponsored contract with the IIT Research Institute (IITRI).

This report was prepared for the Systems Research and Development Service of the Federal Aviation Administration in accordance with Interagency Agreement DOT-FA70WAI-175, as part of AF Project 649E under Contract F-19628-76-C-0017, by the staff of the IIT Research Institute at the Department of Defense Electromagnetic Compatibility Analysis Center.

To the extent possible, all abbreviations and symbols used in this report are taken from American Standard Y10.19 (1967) "Units Used in Electrical Science and Electrical Engineering" issued by the United States of America Standards Institute.

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EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) is performing a study of VHF Omnidirectional Range (VOR) systems in the state of Alaska. The study requires a knowledge of the coverage provided by existing and proposed sites to determine whether these sites will provide the desired VOR coverage.

The Electromagnetic Compatibility Analysis Center (ECAC) was requested by the FAA to prepare map overlays that indicate the line-of-sight coverage provided by the VOR sites. The overlay-generation process utilizes terrain data to indicate this coverage. An ECAC-developed terrain-data extraction technique based on color-shaded topographic maps was utilized to provide terrain data for those areas of Alaska not covered by information in the existing ECAC topographic data base.

The overlays were generated for 58 sites for five different aircraft altitudes and were forwarded to the FAA under separate cover.

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INTRODUCTION

BACKGROUND

The Federal Aviation Administration (FAA) is performing a study of VHF Omnidirectional Range (VOR) systems in the state of Alaska. The study requires a knowledge of the coverage provided by 31 existing and 28 proposed VOR sites, to determine if these 59 sites will provide the desired VOR coverage. The FAA is concerned with VOR coverage for the entire state; however, its primary interest is in the area of the Alaskan Pipeline.

The FAA requested the Electromagnetic Compatibility Analysis Center (ECAC) to provide composite overlays generated by the Target Acquisition Model (TAM) for line-of-sight coverage at altitudes of 3,000, 5,000, 10,000, 15,000 and 20,000 feet from each of the 59 sites. (These elevation equivalents are 914.14, 1524, 3048, 4572, and 6096 meters, respectively.) A composite view of the entire state was required with separate overlays for the existing and proposed sites.

OBJECTIVE

The objective of this task was to provide the FAA with TAM-developed map overlays indicating the coverage, or lack of coverage, for existing and proposed VOR sites in Alaska.

APPROACH

The preparation of TAM overlays for a particular site requires terrain information in the vicinity of that site. The locations of the Alaskan VOR sites required data that was not available in the ECAC topographic data base. Determination of the missing data blocks and the temporary entry of missing data into the ECAC Topographic Data Base were the first steps toward accomplishing the task. A review of site locations and data requirements indicated that a total of 156 blocks would have to be extracted to provide the topographic data required for the TAM overlays.

It was determined that normal ECAC topographic-data-extraction techniques would not permit completion of the task in the required time. Therefore, a new method of extraction was developed to provide the needed terrain data. This method, referred to as the Chromatic Extraction Technique (CET), made use of small-scale color maps. The method is described in APPENDIX A.

Overlay preparation was completed after presentation of results of an initial test to the FAA early in the task period. The review of that output indicated that the final overlays should be made at a scale of 1:3,295,000 to be used with a National Geographic Society map of Alaska. A test sample overlay was delivered early in the task period as an indication of the scale of the final overlays and the layouts of sites to be represented.

SECTION 2

ANALYSIS

FAA ALASKA VOR COVERAGE

The VOR system is the primary navigational facility for civil aviation in the U.S. The VOR generates directional information and transmits it by ground equipment to an aircraft, providing 360 magnetic courses to or from the VOR site. Thus, the pilot determines and controls his ground track on the basis of his instrument indications.

The FAA is presently performing a study to determine the number and location of new VOR sites required to provide adequate VOR coverage in Alaska. This study considered the existing 31 VOR sites and 28 proposed sites. TAM overlays were generated to indicate the coverage provided by each site.

The proposed and existing VOR sites are given in TABLE 1 and TABLE 2, respectively. These tables give the location of the sites and the source of data used in the generation of the TAM-generated overlays.

TABLE 1

PROPOSED VOR SITES

ECAC Site #	Facility	Latitude (N)	Longitude (W)	Terrain Data Source	
				CET[a]	DMA[b]
1	St. Marys	62 04 00	163 18 00	X	
2	Sparrevohn	61 06 00	155 35 00	X	
3	St. Paul	57 10 00	170 13 00	X	
4	Haines	59 15 00	135 31 00	X	
5	Barter Island	70 08 00	143 35 00	X	
6	Chandalar	67 30 00	148 29 00	X	
7	Cape Newenham	58 39 00	162 04 00		X
8	Cape Spencer	58 12 00	136 38 18	X	
9	Cape Yakataga	60 05 00	142 30 00		X
10	Cordova	60 30 00	145 29 00		X
11	Iliamna	59 45 00	154 55 00		X
12	Puntilla Lake	62 04 26	152 43 51		X
13	Sagwon	69 22 00	148 42 00	X	
14	Wien Artic Vlg	68 06 00	145 35 00	X	
15	Bornite	66 57 00	156 54 00	X	
16	Umiat	69 23 00	152 10 00	X	
17	Wainwright	70 38 00	160 02 00	X	
18	Aniak	61 35 00	159 32 00		X
19	Summit	63 20 00	149 07 00		X
20	Minchumina	63 53 00	152 18 00		X
21	Lonely	70 55 00	153 14 00	X	
22	Stevens Vlg	66 01 00	149 06 00	X	
23	Cape Lisburne	68 53 00	166 07 00	X	
24	Adak	51 53 00	176 39 00	X	
25	Amchitka	51 23 00	179 16 00[c]	X	
26	Nikolski	52 57 00	168 51 00	X	
27	Port Heiden	56 58 00	158 39 00	X	
28	Cape Sarichef	54 35 00	164 55 00	X	

[a] Chromatic Extraction Technique

[b] Defense Mapping Agency

[c] Site is east longitude

TABLE 2

EXISTING VOR SITES

ECAC Site #	Facility	Latitude (N)	Longitude (W)	Terrain Data Source	
				CET[a]	DMA[b]
29	Gulkana	62 09 15	145 26 53		X
30	Homer	59 42 36	151 27 16		X
31	Johnstone Point	60 28 58	146 35 50		X
32	Kenai Muni	60 36 55	151 11 35		X
33	King Salmon	58 43 31	156 45 00		X
34	McGrath	62 57 06	155 36 33		X
35	Middleton I	59 25 21	146 20 54		X
36	Northway	62 56 51	141 54 38		X
37	Talkeetna	62 17 57	150 06 12		X
38	Anchorage Intl	61 09 05	150 12 16		X
39	Bethel	60 47 08	161 49 19		X
40	Big Lake 2	61 34 12	149 57 54		X
41	Dillingham	58 59 42	158 32 59		X
42	Annette Island	55 03 39	131 34 36	X	
43	Bettles	66 54 20	151 32 00	X	
44	Big Delta	64 00 17	145 42 53	X	
45	Biorka Island	56 51 35	135 32 58	X	
46	Cold Bay	55 16 06	162 46 20		X
47	Fairbanks Intl	64 48 02	148 00 34	X	
48	Ft. Yukon	66 34 29	145 16 27	X	
49	Galena AFS	64 44 20	156 46 29	X	
50	Kodiak	57 46 33	152 20 16	X	
51	Kotzebue	66 53 11	162 32 15	X	
52	Level Island	56 28 05	133 04 53	X	
53	Moses Point	64 41 50	162 04 07	X	
54	Nenana Muni	64 35 26	149 04 14	X	
55	Nome	64 29 09	165 15 05	X	
56	Sisters Island	58 10 41	135 15 25	X	
57	Tanana	65 10 40	152 10 29	X	
58	Unalakleet	63 53 34	160 40 55	X	
59	Yakutat	59 30 40	139 38 47	X	

[a]Chromatic Extraction Technique

[b]Defense Mapping Agency

CHROMATIC EXTRACTION TECHNIQUES (CET)

The CET system was utilized to provide terrain data for areas where previously requested data from the Defense Mapping Agency (DMA) was not available and was not expected within the time frame required by the FAA. Normal ECAC data extraction techniques were reviewed and it was determined that extraction time (22 man years) was far in excess of available manpower.

Due to time constraints, it was determined that the use of color shading for extracting terrain-elevation information from maps instead of reading each contour was the best available method if an approximation of the terrain was sufficient for the TAM-generated overlays. The World (North American) 1:1,000,000 was the basic map used for the majority of the state, with the Alaska topographic series 1:250,000 used where the small-scale maps were not available.

It must be noted that the CET technique of data extraction from maps does not provide exact values for the terrain points used within the areas of the coverage indicated on the overlays.

Gradient tints used for the initial entry of data represent elevations with a range of values up to 1500 meters (4921 feet). Entries were made using the highest value for each color, thereby providing what may be considered the "worst case" when coverage diagrams are required.

With the CET, data refinement was accomplished for an area of 100 square miles (259.067 square kilometers) centered on each of the sites using large-scale maps. This combination of the accurate data close in and the CET data farther out from the sites should be considered when the value of the overlays is being determined.

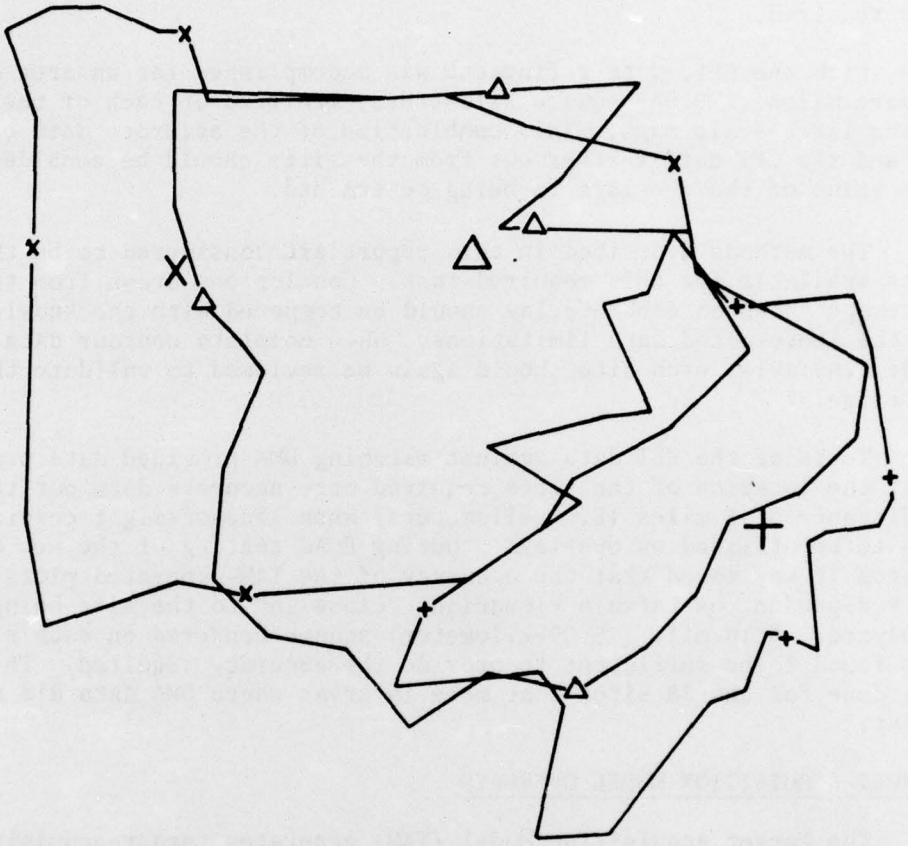
The methods described in this report are considered to be the best available for this required task. Conclusions drawn from the coverage shown on each overlay should be tempered with the knowledge of the above-noted data limitations. When complete contour data is made available, each site should again be reviewed to validate the coverage.

Tests of the CET data against matching DMA-provided data proved that the location of the sites required more accurate data out to a distance of 5 miles (8.05 kilometers) when line-of-sight coverage was to be utilized on overlays. During ECAC testing of the new CET system it was found that the accuracy of the TAM-generated plots was very dependent on terrain elevations "close in" to the site being analyzed. A 10-mile (16.09-kilometer) square centered on each site was found to be sufficient to provide the accurac, required. This was done for the 38 sites that were in areas where DMA data did not exist.

TARGET ACQUISITION MODEL OVERLAYS

The Target Acquisition Model (TAM) generates target-acquisition contour information about specified site locations to enable assessment of site suitability with respect to the detection of aircraft.

Given a site location, the definition of the desired area around the site and an aircraft altitude, terrain profiles along a number of equally spaced radials projecting from the site are generated. An analysis of these profiles allows the determination of distance at which aircraft, approaching the site at a given altitude, will be detected. This information is consolidated to produce contours around the site. Figure 1 is a sample plot showing contours around 3 sites. The location of each site on the overlay is identified by the noted symbol. In Figure 1, + identifies the location of Wien Artic Village. This same symbol also serves to identify the contour that is associated with this site.



SITE ID	SITE SYMBOL	AREA OF COVERAGE
SAGWON	△	△——△
WIEN ARTIC VILLAGE	+	+——+
UMIAT	X	X——X

Figure 1. Sample overlay plot of sites 13, 14, 16 (not to scale).

The TAM uses the ECAC Topographic Data Base to generate the terrain profile. As mentioned previously, DMA topographic data was supplemented as needed by CET extracted data. Figure 2 shows the location of sites and data sources used for this task.

The overlays were prepared in groups of sites to provide maximum clarity of coverage where sites are close together. TABLE 3 shows the groupings. Site numbers shown are those found in TABLES 1 and 2.

TABLE 3

FAA SITE OVERLAY IDENTIFICATION

Overlay Numbers[a]	Site Numbers[b]
E1-3, E1-5, E1-10, E1-15, E1-20	30, 39, 42, 46, 47, 48, 49, 50, 52, 53, 54, 56
E2-3, E2-5, E2-10, E2-15, E2-20	33, 35, 36, 43, 44, 45, 51, 55, 57, 58, 59
E3-3, E3-5, E3-10, E3-15, E3-20	29, 31, 32, 34, 38, 40, 41
P1-3, P1-5, P1-10, P1-15, P1-20	5, 8, 9, 13, 14, 15, 16, 17, 18, 20, 21
P2-3, P2-5, P2-10, P2-15, P2-20	1, 4, 7, 12, 22, 23, 24, 27, 28
P3-3, P3-5, P3-10, P3-15, P3-20	2, 3, 6, 10, 11, 19, 25, 26

[a] Overlay numbers shown as EX-X are plots of existing sites and those shown as PX-X are plots of proposed sites. The numbers listed to the right of each letter represent the set of sites and the target altitude (in thousands of feet). Example: E1-10 represents the overlays for the first set of existing sites with a target altitude of 10,000 feet (3048 meters).

[b] Existing site 37 was not plotted, because the DMA terrain data was found not to be suitable. The CET will be used to obtain necessary data for overlay generation if desired by the FAA.

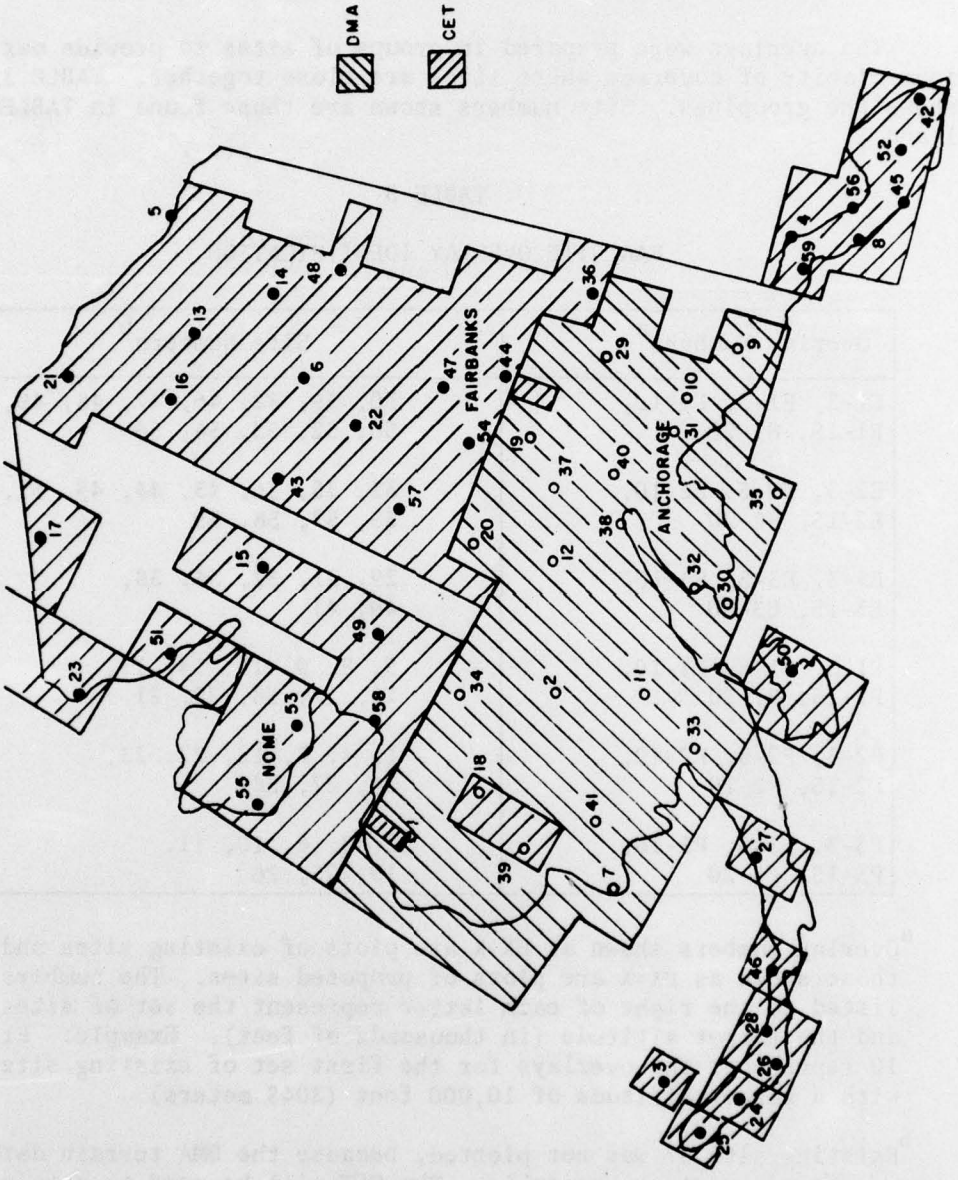


Figure 2. FAA VOR site requirements.

SECTION 3

RESULTS

RESULTS

1. VOR coverage overlays were prepared for 58 sites at altitudes of 3,000, 5,000, 10,000, 15,000, and 20,000 feet and were supplied to the FAA under separate cover. (The altitude equivalents are 914, 1524, 3048, 4572, and 6096 meters, respectively.)

2. Terrain data for areas of Alaska not covered by DMA data was extracted from color-shaded maps using the CET technique and was stored for possible future reference.

APPENDIX A

CHROMATIC EXTRACTION TECHNIQUE (CET)

A method of extracting topographic data from small-scale maps, using gradient tints in place of elevation contours, was developed to provide an approximation of the terrain for areas where no other terrain data was available. The system is known as the ECAC Chromatic Extraction Technique (CET). The user of data extracted with this technique should be aware that this is a rather coarse approximation of the actual terrain.

The CET is designed for use with specific types of maps that can be read quickly by using gradient tints in place of the elevation contours normally found on large-scale topographic maps. The World (North America) 1:1,000,000 map series was found to be suitable and, in most cases, was available for the particular area (Alaska) for which the technique was developed. As a supplement, the 1:250,000 topographic series was utilized. Figure A-1 is a representation of a gradient tint map, where it can be seen that a tint represents a range of elevation values. For example, elevations from 0 to 150 meters (0 to 492.125 feet) are represented by one tint.

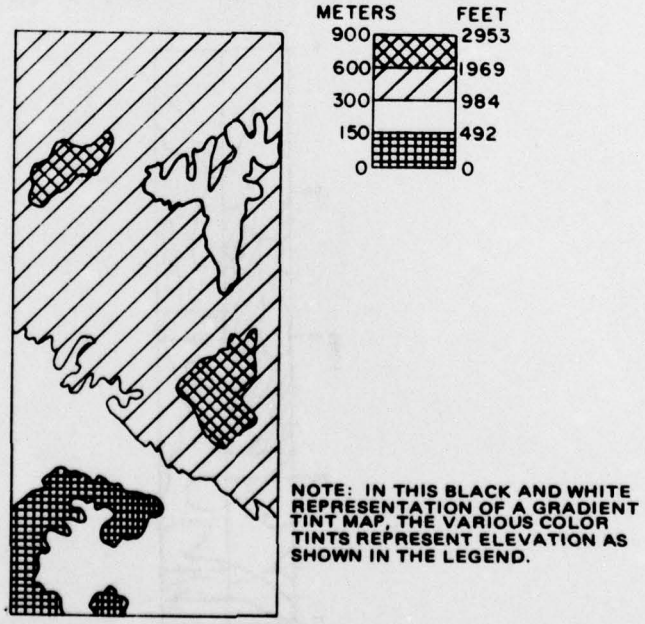


Figure A-1. Sample gradient tint map.

Data was extracted to provide the equivalent of 30-second entries in both latitude and longitude. Data block size was 1 degree by 1 degree. This resulted in 121 data points in both north/south and east/west directions for a total of 14,641 entries to complete each block.

To process the data from extraction to entry into the ECAC topographic data base, the following procedures were followed.

DATA EXTRACTION

Determination of the number of elevation points to be read was a result of a combination of factors. These factors included the scale of the maps used as the basic map, accuracy of the gradient tints, range of values in each color, manpower expenditure, and expected usage of the data. Figure A-2 shows a portion of a data block with the grid markings used in the extraction. These factors resulted in the reading of the data at each point (rows) in a north/south direction with every fifth point (columns) in an east/west direction, for a total of 3,025 points extracted. This resulted in a 121 X 25 data-point matrix. An available program was utilized to expand this to a 121 X 121 matrix, to provide the 14,641 data points required in the ECAC topographic system.

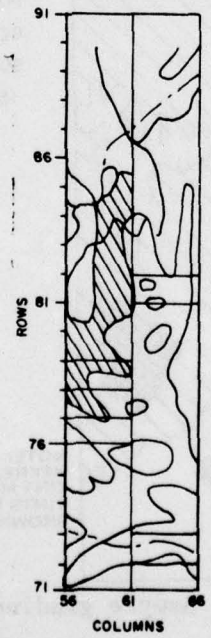


Figure A-2. Portion of data block with grid marking used in data extraction.

Entries were made for the highest elevation value represented by each color thereby providing the "worst case" value of each elevation. The result was an approximation of the terrain to be used in the determination of aircraft-acquisition capability at various altitudes.

SITE DATA MODIFICATIONS

Early tests indicated that within line-of-sight of a specific location, the CET data was too coarse and greater accuracy was required if reasonable acquisition distances of targets was to be portrayed. To modify the data, maps of a scale 1:63,360 or 1:250,000 were used with data points extracted at 30-second intervals within a 100-square-mile (259-square-kilometer) area centered on each site. Data for a total of 38 sites was modified in this manner.

APPENDIX B

ACRONYMS AND ABBREVIATIONS

The following entries comprise the acronyms and abbreviations in this report.

CET - Chromatic extraction technique.

DMA - Defense Mapping Agency.

DoD - Department of Defense.

DOT - Department of Transportation.

ECAC - DoD Electromagnetic Compatibility Analysis Center.

FAA - Federal Aviation Administration.

TAM - Target acquisition model.

VHF - Very high frequency.

VOR - VHF omnidirectional range.

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